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while the production of rubber from *Hevea* varied from 13,469 to 16,546 tons.

The central and upper Amazon Basin are now the most important fields of rubber production. It is interesting to observe the relative importance of the various rivers in production. In 1903 the upper Amazon, with the Javary and the streams above Iquitos, yielded 4,130 tons; the Juruá, 4,537; the Purús, 7,395; the Madeira, 2,963.

Various attempts have been made along the Amazon to form plantations of *Hevea* trees. These experiments have not been very successful, and the fact has been chiefly ascribed to the comparatively high price of labour and the inability of the planters to give adequate care to the young trees. There seems to be no doubt, however, that rubber trees may be successfully raised on Brazilian plantations. Experiments show that a tree of *Hevea Brasiliensis* in a well-kept plantation will yield within fifteen years after planting, while a tree in the forest requires twenty-five years.

The fact is now well known that many comparative experiments in tropical countries with some or all of the established rubber plants have demonstrated the superiority of *Hevea Brasiliensis*. One of the latest accounts is from Mr. W. H. Johnson, Director of Agriculture on the Gold Coast, West Africa, who reports that experiments in the botanic gardens at Aburi were unsuccessful with West African, Ceará, Assam, and Central American rubber plants. Fairly satisfactory results were obtained with the indigenous *Funtumia elastica*; but *Hevea* excelled in quantity and quality of rubber and in its rate of growth, and has been remarkably free from insects and fungus pests.

TOPOGRAPHY AND TRAVEL IN PENNSYLVANIA.

BY

WALTER S. TOWER.

The earliest lines of travel in Pennsylvania, Indian trails, and tracks through the wilderness took little heed of surface form. On the old maps many trails may be seen running directly across steep mountain ridges and through deep valleys, with no apparent attempt to seek out the easiest routes. To-day the more improved modes of travel seem to be less independent. Throughout the State, both highways and railroads are directly controlled by the topographic conditions of the region.

Pennsylvania may be divided, on the basis of general features, into three main topographic districts, each one quite different from the others, and together presenting a variety hardly equalled in any other State. The three districts are: (1) the southeast district, a region of small relief; (2) the central district, a region of parallel ridges and linear valleys; and (3) the western district, a region of many streams and steep-sided valleys, with intervening even-topped hills. When each of these districts is considered in detail it is seen that as the topography varies the conditions of travel also vary.

The southeast district includes the area south and east of South Mountain, together with the region lying between South and Kittatinny or Blue Mountain, commonly known as the Cumberland or Great Valley. In comparison with the rest of the State, this district is a region of small relief; it is not a plain, however, in the strict sense of that term, being characterized throughout by a rolling topography of varying altitudes. When studied in detail there appear to be three divisions of the district: (1) The lowland areas, represented by the Great Valley, the Chester Valley, and the Lancaster plain; (2) the extreme southeastern belt of low hills in Philadelphia, Delaware, and Chester Counties; and (3) the range of hills known as South Mountain, extending from the Delaware River at Easton southwestward to Reading, where they die down not to appear again until the Susquehanna River is passed in York and Cumberland Counties. In each one of the smaller divisions the topography is characteristic and exerts its controls over travel.

Throughout the Great Valley, the Lancaster plain, and the other lowland areas the surface is that of a gently-rolling or undulating plain; streams are many, but there are no deep valleys, and though the surface is far from level, hills of any prominence are few and scattered. Over such a region travel moves with equal facility in all directions. The highways often present a rectilinear pattern, being parallel to, or at right angles to, the undulations. They usually represent the shortest distance between the different points of communication, and over a given area they reach a maximum value of mileage, averaging even in some of the less populated parts two and three miles of highways per square mile of area. Railroads, likewise, find nothing to restrict their direct routes. There are few steep grades to be climbed, few cuts to be made, and few valleys to be bridged. The several lines radiating from Lancaster, from New York, or from Lebanon all show the freedom of communication which exists.

In the area of low hills beginning to the north of Philadelphia

and extending southwest into Chester County there are no great elevations, the relief rarely exceeding 200 to 300 feet; steep slopes and cliffs are generally absent, and the whole contours take on a softened, rolling outline. The conditions are much like those in the lowland areas. Travel by highways is unrestricted; no slopes are so steep as to be forbidding, and no heights are so great as to make detours easier or more economical. Away from the larger towns there are often two or three miles of road per square mile of area. The railroads, however, find the conditions a little less free. Where convenient stream-courses offer easy grades along their banks, the railroads follow the streams, as in the case of the two main lines along the Schuylkill, and the smaller lines along Darby, Chester, and Brandywine Creeks. The main line of the Pennsylvania Railroad, however, finds it more economical to save distance even at the expense of numerous cuts and bridges, and hence runs out across country to the level region of the Chester Valley.

In the South Mountain belt there is not, as in the case of the other mountains of the State, a solid, steep-sided, even-crested wall of rock, but rather a broken chain of detached hills of varying height and extent. Few of them are continuous elevations for more than a mile, being generally rounded rather than linear, and few of them rise more than 600 or 700 feet above the level of the surrounding country. The control of travel is more marked here than in the other two areas. The highways can, and in many places do, run across country, irrespective of the hills that intervene, but by far the greater number of them swing around the hills, keeping to the lower levels and seeking the lower divides, even at the expense of greater distances to be travelled. The relief is great enough to make many routes impossible for the railroads. The degree to which the country is intersected by streams results in there being no continuous, easy slopes, except along the winding-stream valleys; and in them the railroads are compelled to locate. In the fifty miles from Easton to Reading the South Mountain belt is crossed but twice by the Bethlehem and Allentown branches of the Reading Railroad, both of which are single-track lines, and are compelled to follow up the creek to cross over to another descending on the other side. On the Allentown branch a tunnel a half mile long is necessary to get from the headquarters of the Perkiomen to the valley of Little Lehigh Creek.

In the same way the south prong of the South Mountain, in

York and Cumberland Counties, is crossed but once in its extent of forty miles in this State by the road from Carlisle to Gettysburg, which follows up the valley of Mountain Creek to descend on the south by the valley of the Conestoga. Thus, in the southeast district there is the open communication of the Great Valley and the lowland areas; the beginning of restriction in the southeastern belt of hills, and the still greater restrictions in the South Mountain belt.

For the sake of direct comparison, let us pass next to the western district, which may be considered as including all the area west and north of the Allegheny Mountains. In this district the relief is everywhere great, and though the hills, viewed from a distance, present the effect of a generally uniform level, the difference between the upland level and the valley bottoms is often 1,500 feet. The slopes are often steep; cliffs are not infrequent, and many of the valleys are of the character of narrow, steep-sided, V-shaped ravines. The streams and their tributaries are numerous and ramified, which, together with the narrow character of the valleys, results in there being neither continuous stretches of unbroken upland nor extensive areas of lowland. Though the conditions of actual elevation above sea-level, amount of relief, etc., vary here and there in the district, the controls of travel are so similar throughout that it may be regarded as a unit.

The first interesting feature is the control exerted by the Allegheny Mountain, the eastern boundary of the district. The Allegheny Mountain, which is really only the southeast-facing escarpment of the plateau lying to the west, extends almost unbroken in a long, sweeping curve from the Maryland line in Somerset County to within twenty miles of the northeast border of the State. It is a wall of rock about 2,000 feet high, and in its extent of 230 miles in this State it is broken only by the narrow gorges of long cañons, through which flow the northwest branches of the Susquehanna River. These branches are six in number, and are located mainly near the eastern end of the mountain; in order, westward, they are the North Branch of the Susquehanna, Muncy Creek, Lycoming and Pine Creeks, West Branch of Susquehanna, and Beech Creek. South from the gorge of Beech Creek the mountain is unbroken as far as the Maryland line, but is deeply notched in its crest by several short ravines.

These six ravines offer the only avenues of communication with the northwestern part of the State and between central Pennsylvania and New York State. Each one of them is occupied by a

railroad, the lines from Williamsport to Elmira along the Lycoming and from Lock Haven westward along the West Branch being the most important. South from Beech Creek the Allegheny front is crossed but five times by railroads in the hundred miles to the Maryland line. Four of these lines are between Beech Creek and Gallitzin, three short coal roads, and the main line of the Pennsylvania Road to Pittsburg. In each case the ascent is made at the only points where the crest is notched by short ravines, and even then the roads are forced to maintain steep grades. In the case of the Pennsylvania Road the ascent from Altoona at the base of the mountain is made only by means of the famous "Horseshoe curve" and heavy grades to the tunnel at Gallitzin, several hundred feet below the crest of the Front. From Gallitzin to the Maryland line, about forty miles, there is but a single notch in the crest, the one occupied by the Baltimore and Ohio on its way from Cumberland over to Pittsburg. To make this ascent at all such heavy grades are necessary that extra engines are detailed to help the traffic over that portion of the road; and for this work the largest engine in the world has been built recently. Both the notch at Gallitzin and the one occupied by the Baltimore and Ohio are located opposite westward-flowing streams, the Cone-baugh and Castleman Rivers, which afford comparatively easy routes through the hilly country to the west.

In all the region that lies beyond the Allegheny Front the movement of travel is almost entirely dependent on the occurrence and extent of stream-courses. Over thousands of square miles hardly a mile of railroad can be found which does not faithfully follow the course of some stream, large or small, as the Allegheny, Monongahela, Conemaugh, Kishiminetas, Red Bank, and a host of others. The reason lies plainly enough in the dissected character of the country; a region broken by ramified streams into an endless variety of detached hills, with many deep valleys, whose narrow floors or sloping sides offer the only continuous levels for railroad-building. The absence of large streams, and consequently favourable routes, has left tracts of hundreds of square miles in the midst of the bituminous coal regions still unentered by railroads.

The highways, also, are almost without exception located in or along the valley bottoms or sides. Some few roads gain the hill-tops, and run from one to another in a winding course for several miles, but they for the most part follow up one ravine to the lowest divide and descend by the opposite ravine on the other side. Between any two points the topography determines the direction

of the route. Here the ratio of miles of road to unit of area is at a minimum; in places many square miles of territory are without roads of any kind, or only those of the most primitive sort. The miles of trails and mere tracks leading over the steep hills suggest the conditions of a truly mountainous region.

In sharp contrast with these conditions is the freedom of movement over the narrow Erie lowland, generally level, and of low relief. Over the lowland travel moves at will; and the two great trunk lines of railroads, which utilize it as an easy gateway to the west, run in wonderfully straight lines when compared with the winding and circuitous routes along the rivers in the hilly country near by.

The central district, the last to be considered, lies between the Allegheny Mountain and Kittatinny or Blue Mountain, and is divided into four well-defined topographic areas: (1) the Catskill or Pocono plateau, at the northeastern end; (2) the anthracite coal region; (3) the open country of the Middle Susquehanna; and (4) the mountains of the Juniata region.

After crossing the Delaware River into Pennsylvania, the Catskill Mountain plateau of New York State extends as a high table-land westward over northern Pike, Monroe, and Carbon Counties to the Lehigh River. The whole plateau is a nearly level upland, over which, when once the general level is reached, travel is not difficult. Highways are few as compared with the other parts of the State, mainly because there is no demand for them; but six lines of railroads cross the plateau from the coal fields to reach the seaboard markets. Here, as along the Allegheny Mountain, the lines of railroads ascend and descend the rim by the short ravines that notch it, as Spring Brook and Roaring Brook on the western edge and Lackawaxen Creek on the east.

The anthracite coal fields, perhaps, present the most interesting series of controls of travel to be found in the State. The coal basins are, from their shut-in nature, not easily accessible; but their great mineral wealth demands an outlet, and hence hundreds of miles of railroads have been built where otherwise, probably, not a mile of track would have been laid. The basins are bounded and traversed by a series of parallel and converging ridges, even-crested, steep-sided, and of great linear extent, which rise 1,000 feet above the intervening valleys.

Though the floors of the valleys are far from level, the differences in elevation are comparatively unimportant; and in any given valley the travel both by highways and by railroads is hardly more limited than in the hilly country of the southeast province.

Only when it is a matter of inter-valley communication do the real difficulties appear. Over most of their extent the ridges present solid barriers to transverse travel. In places, however, their crests are lowered either by slight Vs, in a notch a few hundred feet deep, or in narrow gashes all the way down to the level of the neighbouring valleys. The former are known as wind-gaps, the latter as water-gaps. The importance of these gaps cannot be overestimated; toward them nearly all lines of inter-valley travel are seen to converge, and often the larger towns, as Shamokin and Pottsville, are located at these natural centres of communication.

On the south and east the coal basins are shut in by the Blue Ridge and the Pocono plateau, already mentioned. The Blue Ridge, in its extent of 100 miles from the Delaware River to Harrisburg, is breached but three times by the Lehigh River below Mauch Chunk; by the Schuylkill at Fort Clinton; and finally by the Swatara. Not one of these gaps exceeds a quarter of a mile in width, and yet they furnish the only gateways from the southeast through the high rampart of the Blue Ridge to the rich coal fields of Schuylkill, Carbon, and Luzerne Counties. The gap of the Lehigh at Mauch Chunk not only acts as an outlet for the eastern part of the southern coal fields, but also takes a large share of the traffic from the northern field.

The northern field in Wyoming and Lackawanna Counties has a natural outlet both to the west and to the north along the east branch of the Susquehanna River. To the west, however, is away from the markets, and to the north the course of the stream is so winding, and the valley so narrow and steep-sided, that most of the coal roads choose the shorter course, and make the difficult ascent of the Pocono plateau rim to reach the seaboard markets.

In the southern coal fields the problem of travel and transportation is complicated by the fact that each basin has a double rim; that the gaps in the bounding ridges are sometimes not opposite each other, and also not opposite the gaps in the Blue Ridge, or that there are no convenient gaps at all. For example, there is but a single eastern or southern outlet from the Shamokin field—the gap near Mt. Carmel. But the gap in Locust Mountain, the inner rim, is a little over four miles west of the gap in Mahanoy Mountain, the outer wall; while in front of the latter is Broad Mountain, through which no gap is offered. Between the two gaps the railroad has a comparatively easy, if somewhat longer, route in the narrow valley that separates the ridges; but in getting over Broad Mountain it is necessary to follow up the ravine of Rattling Run,

with a grade above Gordon Station of not less than 200 feet per mile, or about 4 per cent. A grade slightly steeper than this is found near Fairview, a few miles south of Wilkesbarre. A 2 per cent. grade, or 100 feet to the mile, is ordinarily considered as the maximum for all regular traffic. The coal roads out from Tremont, near the western end of the field, find their way easily enough through the gaps in Second and Sharp Mountains, only to be met by the unbroken wall of the Blue Ridge, which makes necessary a detour of seven or eight miles westward to Swatara Gap, or about twelve miles eastward to the Schuylkill Gap.

At Mauch Chunk, at the eastern end of the field, near the famous Lehigh Water Gap through the Blue Ridge, there is no break in the sharp rims of the basins where they converge in the high, prow-like termination. It was here that the famous gravity road was operated from the crest of Summit Hill down to the Lehigh Canal. Since then a tunnel three-quarters of a mile long has been driven through Hesquehoning Mountain to the mines in the valley. Other tunnels are found in different parts of the basins, where no convenient gaps exist—one over half a mile long near Mahanoy City, another about the same length near Williamstown, a smaller one at Lofty, a few miles east of Mahanoy City, and so on.

Still another means that is resorted to in getting over the unbroken ridges is the switchback, the best example of which is on the Clark's Valley branch of the Philadelphia and Reading Railroad over Sharp Mountain, from Clark's Valley to the headwaters of the Swatara. The ascent is nearly 100 feet, made in a double switchback about three miles long—six extra miles of road, with heavy grade, to win a way over a single ridge.

From the end of the line in Clark's Valley to Swatara Gap the nearest break in the Blue Ridge is only six miles. In between, however, lie the ridges of Second and Third Mountains, and to reach the gap the switchback is necessary, together with a detour of over thirty miles along the upper Swatara. In other sections, where but a single route is practicable, it may be followed by two or more rival roads, as the Delaware, Lackawanna and Western and the Pennsylvania Railroads, which parallel each other for miles along the North Branch of the Susquehanna; the Lehigh Valley and the Philadelphia and Reading Railroads, along the Lehigh River; or the Reading and the Pennsylvania lines, along the Schuylkill.

Similar difficulties of unfavourable routes, long detours, and heavy grades are met in all parts of the coal fields, and yet hardly any other section of the State has more miles of railroad per unit

of area. So striking is this feature that on any good railroad map of the State the limits and locations of the different fields can be determined by no other guide than the network of lines covering the basins.

The region of the Middle Susquehanna, the third district of the central province, is an open country, with fewer ridges, broader valleys, and generally favourable conditions of travel. Its main interest lies in the fact that its southern edge contains the gateway to the western part of the State, the gap of the Susquehanna where it crosses the Blue Ridge at Harrisburg. But this gap, important as it is, would be of little consequence without a pathway beyond it. For behind the Blue Ridge, stretching away to the westward, lies the great series of parallel ridges of the Juniata region, which, were they not breached one after another by the transverse course of the Juniata River, would offer an insurmountable barrier to east and west travel. The Juniata pathway leads off from the Susquehanna a few miles above Harrisburg, and though its course, winding about through the ridges, necessitates many miles of extra lines for the railroads that follow it, the importance of its existence there at all can hardly be overestimated.

The last division of the central province, the region of the Juniata, is, like the anthracite coal areas, a region of steep-sided, even-crested linear ridges, sometimes parallel, often converging, and separated by narrow longitudinal valleys. The region is completely walled in on the east by the unbroken rampart of the Blue Ridge from Harrisburg south to the Maryland line. In the valleys the main lines of travel are longitudinal, parallel to the ridges. In any one valley communication is open, and each valley is more or less a unit, as shown by single valleys forming counties, like Juniata, Perry, and Mifflin Counties. Inter-valley travel is, perhaps, even more limited than in the northern area, mainly because of fewer transverse streams to give the advantage of gaps. There is, also, not the great economic need for railroads as in the coal fields. A good example of the difficulty of inter-valley travel is afforded by Bedford in the valley of the Raystown Juniata and McConnellsburg in the valley of Sideling Hill, thirty miles to the east. Between them are two unbroken ridges, and the railroads, paralleling the ridges, necessitate a journey of over a hundred miles between the two towns.

When the State is considered as a whole, one can hardly fail to be struck with the remarkable combination of topographic details, which, by a slight change or omission, might have made a vast dif-

ference in the progress and development of the State. The most open communication is on the southeast, where lines can come from all directions to the only port of the State, Philadelphia. The long break in the South Mountain belt gives easy access to the Great Valley, and opens the way to the middle of the State. Three of the four gaps in the Blue Ridge are in that part of its extent lying in front of the coal fields, to which means of entrance is of the utmost economic importance. The fourth and last gap in the Blue Ridge is opposite the break in the South Mountain, and also in such a place as to be an important part of the gateway to the western part of the State. The gaps are absent only in that part of the Ridge where their need is not great. The transverse course of the Juniata offers a pathway through the otherwise unbroken ridges, from the gap of the Susquehanna to the Allegheny Front at a particular place where crossing is impossible. And, finally, on the western side of the Front, the Conemaugh and Castleman Rivers head near the only points where for miles in extent crossing by railroad is practicable, and offer easy routes for the roads through the broken country of the western district.

THE BIOLOGICAL EVIDENCE OF RIVER CAPTURE.*

BY

DOUGLAS' WILSON JOHNSON.

Whenever one stream captures a portion of the drainage of a neighbouring stream, certain results are produced which become evidences of the capture which has occurred. By a study of these results we are able to tell much about the former relations of the streams affected, and may even learn the approximate time at which the change took place.

It will readily appear that river capture may produce two different classes of results: first, those which can be produced by nothing else than river capture, and which are therefore to be regarded as conclusive proofs of such capture; and, second, those which can be produced by other agencies as well, and which are therefore not in themselves proof of capture. In the study of drainage modifications in general, and in the study of any particular case of capture, it is a matter of prime importance to distinguish

* Abstract of a paper read before the Philadelphia meeting of the Association of American Geographers. The complete paper will appear in "Science," and a full discussion of the Tennessee problem in the *Journal of Geology*.